LONG TERM CARBOHYDRATE INTAKE AND THE EFFECT ON
ENDURANCE PERFORMANCE IN COLLEGIATE DISTANCE RUNNERS

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Marissa Baranauskas

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LONG TERM CARBOHYDRATE INTAKE AND THE EFFECT ON
ENDURANCE PERFORMANCE IN COLLEGIATE DISTANCE RUNNERS

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Thesis

Approved: 

__________________________
Committee Chair
Dr. Ronald Otterstetter

__________________________
Committee Member
Mrs. Laura Richardson

__________________________
Committee Member
Dr. Matthew Juravich

__________________________
Committee Member
Mrs. Michelle Boltz

Accepted: 

__________________________
Dean of the College
Dr. David Gordon

__________________________
Dean of Graduate School
Dr. Chand Midha

__________________________
Date

__________________________
School Director
Dr. Victor Pinheiro
ABSTRACT

Endurance athletes have begun to incorporate adaptive exercise sessions, which include practicing with low carbohydrate availability, into their normal training regimens to elicit a greater endurance response despite recommendations advocating for high carbohydrate diets for adequate recovery from the stresses of endurance training. The purpose of this study was to determine the relationship between dietary carbohydrate intake and indicators of performance in highly trained endurance athletes. Indicators of endurance performance measured were maximal aerobic capacity (VO₂max), fat metabolism during high-intensity exercise (RER 1.0), and overall mood. The self-selected carbohydrate intakes (CHO) of 12 collegiate long-distance track athletes were observed over the course of an eight-week indoor track season. The average carbohydrate intake was 4.11 g·kg⁻¹·body weight·day⁻¹ (SD=1.03), which fell below current recommendations for endurance athletes. Pre-test measures were performed during the initial week and post-testing was conducted during the final week of the season. Participants completed a Costill-Fox maximal aerobic capacity test to observe aerobic capacity (VO₂max) and fat metabolism (RER 1.0). Subjects also completed a Likert-Scale Mood and Lifestyle Questionnaire to determine overall mood scores in feelings of happiness, fatigue, sadness, anger, and worthlessness. Linear regression analysis showed a statistically
significant negative relationship (p < .01) between RER 1.0 and CHO. A significant negative relationship (p < .05) was observed between VO_{2\text{max}} and CHO, but was attributed to gender differences. There was no relationship found between mood scores and carbohydrate intake with high individual variability among subjects. These findings indicate that a decrease in dietary CHO content allowed for an increased capacity for fat oxidation during high-intensity exercise, which may attribute to increases in aerobic performance.
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CHAPTER I
INTRODUCTION

It is recommended that endurance athletes consume a higher amount of dietary carbohydrates than the general population due to their unique energy requirements resulting from long, intense training sessions. The Academy of Nutrition and Dietetics, Dietitians of Canada, and American College of Sports Medicine (2016) recommend endurance athletes to consume 6-10 g CHO·kg⁻¹·body weight·day⁻¹. American and European endurance athletes tend to consume less than the recommended amount of carbohydrates with an average dietary intake of 4-6 g CHO·kg⁻¹·body weight·day⁻¹ (Baranauskas et al., 2015; Barracks et al., 2010; Drenowatz et al., 2012; Wardenaar et al., 2015; Williams, 2004). Additionally, endurance athletes have begun to include adaptive low-carbohydrate sessions into their training to enhance physiological endurance adaptations to training sessions. There is limited research that suggests training with low carbohydrate availability and therefore depleted muscle glycogen may enhance endurance performance by stimulating the expression of genes responsible for adaptation to aerobic exercise (Baar, 2014; Baar & McGee, 2008, Burke & Kiens, 2006). The adaptations made when training is done in conjunction with low muscle glycogen availability include increased mitochondrial development and increases in fat oxidation capabilities.
(Baar, 2014; Baar & McGee, 2008). There is strong evidence to support the transference of these adaptations into improvements in submaximal endurance performance (Ferguson et al., 2009; Lima-Silva et al., 2009). However, the effect of low carbohydrate training practices is unclear at high-intensity exercise at or near-maximal performance such as in collegiate distance events of the 5-kilometer and 10-kilometer races (Havemann et al., 2006; Lima-Silva et al., 2013). Training with low muscle glycogen has been associated with increased fatigue and compromised immune system response, which may impair recovery and lead to compounding training stress over time with low-carbohydrate diets (Halson & Jeukendrup, 2004). Increased training stress beyond the ability to recover has the potential to decreased athlete performance due to injury, illness, and decreased mood state.

Higher carbohydrate diets have also been shown to elicit similar metabolic responses to endurance training and may have an additional advantage of mitigating the undesired stress response to intense exercise (Akerstrom et al., 2009; Cox et al., 2010; Gleeson et al., 2004; Ihalainen et al., 2012). Consuming high amounts of carbohydrates following bouts of high-intensity endurance exercise is needed to replace muscle glycogen for adequate recovery between training sessions (Alghannam et al., 2015; Skein et al., 2012). Low muscle glycogen availability has been associated with fatigue and undesired responses to training such as mood disturbances (Halson & Jeukendrup, 2004). High carbohydrate diets have demonstrated the ability to prevent against fatigue and improve the capacity for repeated bouts of high-intensity exercise through the restoration of muscle glycogen (Alghannam et al., 2015; Cermak & van Loon et al., 2013; Foskett et al., 2008; Karelis
et al., 2010; Kasikcioglu et al., 2008; Knicker et al., 2011; Skein et al., 2012). There is limited evidence available to suggest that high carbohydrate diets lead to improvements in endurance performance.

Therefore, it is the purpose of the present study to observe the dietary habits of trained collegiate endurance athletes to investigate the relationship between low- and high-carbohydrate diets and endurance performance. Specifically, the relationship between carbohydrate intake and indicators of endurance performance that include aerobic capacity, fat metabolism, and mood state were observed. From the current literature, three research questions emerged.

1) Is there a correlation between carbohydrate intake (CHO) and maximal aerobic capacity (VO$_{2\text{max}}$) in trained distance runners?

2) Is there a correlation between carbohydrate intake (CHO) and the time it takes for the respiratory exchange ratio to equal 1.0 during maximal aerobic exercise (RER 1.0) in trained distance runners?

3) Is there a correlation between carbohydrate intake (CHO) and mood scores in trained distance runners?
CHAPTER II
REVIEW OF LITERATURE

It is recommended that endurance athletes need a higher daily dietary intake of carbohydrates than the general population because of their increased energy needs incurred from training. In a joint position statement, the Academy of Nutrition and Dietetics, Dietitians of Canada, and American College of Sports Medicine (2016) recommend competitive endurance athletes consume 6-10 g CHO·kg⁻¹ body weight·day⁻¹ to adequately maintain blood glucose during exercise and replace muscle glycogen after exercise. Some researchers advocate that an even greater carbohydrate intake of 12-13 g CHO·kg⁻¹ body weight·day⁻¹ may be necessary for individuals who undergo intense or strenuous training sessions, such as endurance athletes (Burke et al., 2004). Patterns of high carbohydrate intake are evidenced in practices of some of the most successful distance runners in the world, notably Kenyan and Ethiopian endurance athletes, who consume an average of 9.7-10.4 g CHO·kg⁻¹ body weight·day⁻¹ (Beis et al., 2011; Fudge et al., 2006; Onywara et al., 2004). American and European distance runners, in contrast, tend to consume less than dietary recommendations, with daily carbohydrate intakes ranging from 4-6 g CHO·kg⁻¹ body weight·day⁻¹ (Baranauskas et al., 2015; Barracks et al., 2010; Drenowatz et al., 2012; Wardenaar et al., 2015; Williams, 2004).
Carbohydrates have a significant role in competitive mid- and long-distance running athlete preparation and performance by contributing to the energy pathways utilized during intense exercise training sessions and races. As intensity of prolonged activity increases, the reliance on the anaerobic-glycolytic energy pathways, and carbohydrate as the primary fuel source, subsequently increases (Baar & McGee, 2008; Cermak & Van Loon, 2013; Jeukendrup, 2014; Rapoport, 2010). In the middle distance events, defined as those ranging from the 800-meter to 1500-meter, athletes will perform the majority of their training sessions at intensities above 75% VO$_{2\text{max}}$, which means their primary fuel source is derived almost entirely from glycolytic energy pathways (Stellingwerff et al., 2007). The middle distance events, which are several minutes in duration and performed at, or near, maximal capacities also rely partly on anaerobic pathways for energy contributions.

Even the long-distance races ranging from the 5,000 to 10,000-m, although categorized as predominantly endurance events, display a small, but meaningful, anaerobic-glycolytic component. Especially in highly trained endurance athletes, changes in intensity such as pace-shifts during the middle portion or final portion of the event relies on switching from aerobic to anaerobic substrate derivation. Research findings support the causal role that carbohydrates lend to anaerobic portions of distance races. In a study of trained male adolescent distance runners, faster overall 10-kilometer and final 400-meter sprint times were observed in a group consuming a high carbohydrate diet of 7.1 ± 2.6 g·kg$^{-1}$·day$^{-1}$
compared to a low-carbohydrate diet group (Couto et al., 2015). Although considered predominantly endurance events, middle- and long-distance races ranging from the 800 to 10,000-meter, require some glycolytic-anaerobic contribution during variations in intensity and as such a reliance on carbohydrates as the substrate driving these pathways.

Carbohydrates are a major fuel source during competitive endurance training and have the capacity for depletion after intense, long-duration training sessions. Carbohydrates stored in liver and muscle glycogen will only supply 350-650 kilocalories of exercise (Rapoport, 2010). Adequate carbohydrate intakes during the recovery period may improve the capacity for performing and recovering from repeated bouts of high-intensity exercise by restoring muscle glycogen stores. Current research suggests that there is a direct and positive relationship between the amount of dietary carbohydrate intake and post-exercise glycogen storage content (Burke et al., 2004). The ability to adequately recover and maintain performance in repeated high-intensity exercise sessions is relevant to competitive endurance athletes. It is not uncommon for training of endurance athletes to involve high-intensity interval sessions with varying recovery periods and competition may require an athlete to compete in multiple events separated by relatively short periods of time (Burke, 2010; Cermak & van Loon, 2013).

Research suggests that carbohydrates, when taken during the recovery period, after high-intensity long-duration workouts, may replenish glycogen stores and restore the capacity for repeated work while maintaining intensity. Repeated
run to exhaustion times at 70% of VO$_{2\text{max}}$ improved by 31 ± 9 minutes in endurance trained subjects who ingested a high carbohydrate solution during a four hour recovery period (Alghannam et al., 2015). Subjects also demonstrated a 21 percent improvement in high-intensity intermittent running capacity to fatigue after consuming a 48-hour high carbohydrate diet along with carbohydrate supplementation during the exercise bout (Foskett et al., 2008). Physically active participants who consumed a 7 g CHO·kg$^{-1}$·body weight·day$^{-1}$ diet without supplementation were able to complete longer total and hard running distances during a 60-minute intermittent sprint protocol that consisted of 15-m maximal sprints at self-paced efforts (Skein et al., 2012). The increased ability to perform repeated bouts of high-intensity exercise were accompanied by increases in muscle glycogen content, demonstrating the positive relationship between muscle glycogen storage and dietary carbohydrate intake (Alghannam et al., 2015; Skein et al., 2012).

Inadequate recovery from training stress may result in the development of a common phenomenon in endurance athletes, overreaching or overtraining syndrome. Overreaching and overtraining syndrome are closely related in their manifestations of symptoms, but differ in the elicitation of responses in the performing athlete. Overreaching is defined as a desired training response that results in recoverable short-term training decrements, but ultimately leads to performance improvements as a result of increased metabolic stress that favors the expression of endurance genes (Halson & Jeukendrup, 2004). Overtraining syndrome is characterized by enhanced symptoms of overreaching and includes
fatigue, illness, performance decline, and mood disturbances and may be caused by an imbalance between training stress and recovery (Halson & Jeukendrup, 2004). While there is not yet one identifiable precursor of overtraining syndrome, it is hypothesized that its emergence may be the result of high intensity exercise combined with insufficient recovery. Therefore, overreaching while neglecting to replenish muscle glycogen stores may contribute to the symptoms of fatigue and decreased performance (Halson & Jeukendrup 2004). A higher daily carbohydrate intake is shown to decrease, but not entirely prevent, the development of overreaching symptoms (Burke, 2010). Adequate carbohydrate intake may contribute to the long-term performance of an athlete by preventing against symptoms of overtraining syndrome.

Fatigue is an identifiable component of overreaching and overtraining syndrome and is a limiting factor in maintaining high-intensity effort for a long duration. It is presumed that fatigue during prolonged moderate-to-high intensity exercise is most often associated with a reduction in muscle glycogen and blood glucose concentrations (Cermak & Van Loon, 2013). Glucose ingestion during exercise has been shown to stimulate the secretion of insulin and rise in plasma free fatty acids, blunting the rise in serotonin and preventing against symptoms of central fatigue (Karelis et al., 2010). Knicker et al., (2011) also supports these findings by demonstrating that decreased carbohydrate availability may elevate serotonin levels and lead to central nervous system fatigue. Cardiovascular fatigue and dysfunction during high-intensity exercise as illustrated by a decrease in cardiac output and delivery of oxygen to working muscles also occurs when done in
association with low glycogen levels (Kasikcioglu et al., 2008). Supporting this evidence, Lima-Sliva et al. (2010) discovered impairment of the autonomic control of heart rate and increased cardiovascular stress after physically active males performed a combination of high volume and intensity exercise with consumption of a 48-hour low-carbohydrate diet. Generalized fatigue through mechanisms of the central nervous system and cardiac muscle fatigue could potentially impair performance by increasing perceived effort and decreasing oxygen delivery capabilities during high-intensity exercise.

Higher-carbohydrate diets are most significantly correlated with improved mood states and psychological parameters such as perception of effort and fatigue. Trained runners who consumed 8.5 g CHO·kg⁻¹ body weight·day⁻¹ had better Profile of Mood States global scores, decreased fatigue, and maintained 16-km all-out run times during a period of intensified training in comparison to a 5.4 g CHO·kg⁻¹ body weight·day⁻¹ diet (Achten et al., 2003). Decreased mood parameters have been evidenced in athletes following long-term low-carbohydrate diets. Despite no significant decline in performance, master endurance athletes reported greater mood disturbances following a 15-day low-carbohydrate diet with increased fatigue, anger, depression, and tension, and decreased vigor (Piacentini et al., 2012). A case study observing a male triathlete on a low-carbohydrate diet during normal training patterns found him to experience significant detrimental effects in his daily training regimen and workout performance. The triathlete experienced persistent fatigue, muscle soreness, lethargy and had incidences of reducing the volume or intensity of
planned workouts (Rosenkranz et al., 2007). High-carbohydrate diets have been shown to attenuate the symptoms of overreaching and overtraining by decreasing fatigue and improving overall mood.

While a higher dietary carbohydrate intake has demonstrated to acutely increase the ability to restore muscle glycogen, adaptations made in response to training may be more predictive of endurance performance success. The physiologic adaptations that occur as a result of endurance training which are most predictive of endurance performance are related to substrate metabolism and mitochondrial enzymatic activity influencing the ability to extract and utilize oxygen in skeletal muscles. AMPK, MAPK, and p38, are proteins that can be up-regulated or down-regulated to enhance the expression of the gene PGC-1 alpha (Baar, 2014; Baar & McGee 2008; Burke, 2010). PGC-1 alpha is a gene that influences muscle mitochondria development, leading to augmented endurance adaptations (Baar 2014; Baar & McGee, 2008). Glycogen content may act as a metabolic signaling regulator, influencing the expression of the PCG-1 alpha gene, with low muscle glycogen increasing activation of these pathways (Baar & McGee, 2008, Burke & Kiens, 2006). Therefore, it is expected that athletes consuming a lower carbohydrate diet may experience enhanced endurance adaptations through greater expression of the PCG-1 alpha gene.

The ability to oxidize fat at higher intensities is another response to endurance training and would increase performance by sparing rate-limiting glucose in turn for fat. Even the leanest athlete can store an exponential amount metabolic potential energy in their adipose tissue, making fat the preferential fuel
substrate for endurance exercise (Rapoport, 2010). However, oxidation of fat is a relatively time-consuming physiological process that depends the ability of training adaptations to efficiently match the rate of energy production to hydrolysis during intense exercise (Stellingwerff et al., 2007). Endurance training enhances the availability of fat as an energy source to working skeletal muscles (AND, 2015). Increases in fat oxidation capabilities at higher intensities have been evidenced with endurance training on short-term low-carbohydrate diets of 2.5 g CHO·kg⁻¹ body weight·day⁻¹ and in fasted states (Burke & Kiens, 2006; Civatarese et al., 2005). It is likely to assume then, that training with low muscle glycogen availability would lead to greater endurance adaptations and performance by enhancing the expression of PGC-1 alpha and increasing the capacity for fat oxidation at higher intensities of exercise.

High carbohydrate diets have been shown to elicit, or at least not interfere with, similar adaptive metabolic responses compared with low carbohydrate diets and may also attenuate the negative stress response associated with intense endurance training. A group of trained cyclists and triathletes that consumed a high-carbohydrate diet for 28-days experienced an increase in maximal citrate synthase and β HAD (Cox et al., 2010). Citrate synthase and β HAD are both enzymes that are increased in a response to aerobic training. Increased citrate synthase and β HAD activity was also found in trained subjects during localized muscular endurance training on a high carbohydrate diet (Akerstrom et al., 2009). Stress responses to endurance exercise include increased cortisol and a depressed immune response
and this response may be exacerbated by low muscle glycogen (Gleeson et al., 2004). After two-weeks on a low-carbohydrate diet, endurance masters athletes exhibited increased baseline cortisol responses to endurance exercise (Piacentini et al., 2012). The cortisol and leukocyte response of recreational runners after a 18 to 20-Km time trial was mitigated by ingestion of a high-carbohydrate fluid solution (Ihalainen et al., 2014). These findings suggest that a higher carbohydrate intake does not interfere with metabolic adaptations to endurance exercise and may prevent against the negative stress and immune responses to intense endurance training.

Low-carbohydrate diets or fasting practices have shown to elicit favorable responses to low-intensity, long-duration endurance exercise sessions. However, an unclear relationship has been established with low-carbohydrate intakes at high and near maximal exercise intensities. After completing a three-week period of caloric restriction that included 2.51 – 3.70 g CHO·kg⁻¹ body weight·day⁻¹ and an overnight fast, trained cyclists reported lower rates of perceived exertion during a two-hour submaximal cycle test. The trained cyclists also exhibited higher power-to-weight ratios with no decrease in maximal cycling performance during an incremental cycling test at maximal capacity (Ferguson et al., 2009). Lima-Silva et al., (2009) found that while time to exhaustion at exercise lower exercise intensities did not differ between physically active males consuming low and moderate-carbohydrates, fatigue during high intensity exercise was attained more rapidly in the low-carbohydrate group (Lima-Silva et al., 2009). At supramaximal exercise
intensities, a 48-hour low-carbohydrate diet also resulted in earlier fatigue (Lima-Silva et al., 2013). Further supporting these results is a study that found impairment in high-intensity sprint exercises by mechanisms of increased sympathetic activation in trained cyclists performing a 100-km time trial who consumed a low-carbohydrate diet (Havemann et al., 2006). These findings suggest that as exercise intensity increases, the aerobic performance benefits of a lower-carbohydrate diet may be reduced.

There has been an emergence of nutritional strategies favoring incorporation of “adaptive” training sessions that consist of performing low intensity and long duration workouts while in a fasted or glycogen-depleted state in endurance trained athletes (Baar, 2014). Practical applications of these adaptive training sessions have been met with mixed responses with some athletes responding favorably and other not responding or responding negatively. In a case study of three elite marathon runners, the athletes adopted several adaptive training sessions per week into their normal training regimen (Stellingwerff, 2012). The adoption of low-carbohydrate availability sessions had a high degree of individual variability; with one marathoner who had previous experience with glycogen depleted training sessions more readily adopting the nutritional practices compared with the other two athletes (Stellingwerff, 2012). All three marathoners had no disturbance in their race performances after incorporation of the sessions (Stellingwerff, 2012). In contrast, in a case study involving the male triathlete he experienced significant training disturbances and psychosomatic issues while adopting a restricted carbohydrate diet, which negatively impacted his training (Rosenkranz et al., 2007).
The varying results of these case studies suggest the possibility of non-responders and responders with low carbohydrate practices during training.
CHAPTER III

HYPOTHESIS DEVELOPMENT

Previous literature suggests that there is a relationship between dietary carbohydrate intake and improvements in aerobic performance. Baar (2014) asserts that low carbohydrate dietary practices lead to greater adaptations to endurance exercise by improving mitochondrial density and therefore aerobic metabolism. Evidencing this theory in application are findings with three elite marathoners that were able to successfully implement low-carbohydrate availability sessions into their long-term training regimen, which resulted in improved performance during their goal race (Stellingwerff, 2012). There is however, a lack of evidence to support a relationship between improved aerobic adaptations and carbohydrate intake. One reason for the lack of sufficient evidence is the short-duration of research studies that have previously examined dietary intake and the effects on endurance capabilities in athletes. Previous studies that have demonstrated a non-significant or a positive relationship between carbohydrate intake and increased aerobic capacity were relatively short in duration lasting from 48-hours to four-weeks, which may not provide sufficient time for changes in endurance adaptations to occur (Couto et al., 2015; Ferguson et al., 2009; Piacentini et al., 2012). It is an aim of the present study to contribute to the deficiency in
research that investigates the effects long-term carbohydrate practices have on aerobic adaptations in trained endurance athletes. Allowing participants to self-select their dietary intakes will result in an accurate representation of their long-term dietary practices. It is estimated that it takes between two to three months for changes in VO$_{2\text{max}}$ to take place in trained individuals (Powers & Howley, 2005). The previous studies may have captured the short-term negative metabolic responses of adjusting to low-carbohydrate diets such as increased perception of effort and lethargy (Baar, 2014). However, the long-term adaptations to the increased metabolic stress of low-carbohydrate diets that include enlarged mitochondrial density and oxygen extraction would theoretically lead to greater aerobic performance after the initial adjustment phase to the low-carbohydrate diet. Therefore, it is hypothesized that there will be a negative relationship between carbohydrate intake (CHO) and aerobic performance (VO$_{2\text{max}}$) in endurance trained athletes.

There is strong evidence from previous research that suggest capabilities for fat metabolism are enhanced among endurance athletes on low-carbohydrate diets. Greater fat oxidation during steady state and high-intensity cycling after 28-days on a low-carbohydrate diet was demonstrated among endurance trained cyclists and triathletes (Cox et al., 2010). Furthermore, lower respiratory exchange ratios and a higher breakdown of intramyocellular lipids for fuel during endurance exercises were observed in physically active males after a six-week intervention of low-carbohydrate availability (Van Proeyen et al., 2011). Lower respiratory exchange ratios, demonstrating a greater reliance on fat metabolism were also observed.
during a 3-day low carbohydrate diet in physically active men during a bout of high-intensity cycling above lactate threshold (Lima-Silva et al., 2009). Findings from previous literature strongly suggest a relationship between low-carbohydrate dietary practices and improved fat metabolism during endurance exercise.

The respiratory exchange ratio (RER) is a ratio of carbon dioxide produced to oxygen consumed and also a physiological indicator of substrate use during activity. When RER approaches a threshold of 1.0, it is indicative of carbohydrates being used as the primary fuel source. In the presences of oxygen, fat oxidation will take place, and is indicated by a RER of .7-1.0. Furthermore, as the availability of carbohydrate decreases, the reliance on fat as a primary fuel source during high intensity exercise will increase. Individuals compensate for decreased availability of dietary carbohydrates and subsequently make adaptations to utilize fat as fuel at greater relative intensities. Also, the aerobic adaptations made in response to low carbohydrate availability will improve the efficiency of extracting and utilizing oxygen at higher intensities of exercises assisting in the capacity for fat metabolism with the presence of more oxygen. Therefore, it is hypothesized that there will be a negative relationship between carbohydrate intake (CHO) and time spent below the fat oxidation threshold of RER 1.0 during high-intensity endurance exercise.

There is also strong evidence to suggest that high-carbohydrate diets may attenuate against the negative mood states associated with overreaching and overtraining syndrome in endurance athletes. Piacentini et al. (2012) observed significantly increased negative mood scores in feelings of fatigue, anger, depression, and tension in masters endurance athletes after two-weeks on a low-
carbohydrate diet. Furthermore, Rosenkranz et al., (2007) found larger disruptions in training and feelings of lethargy in a male triathlete on a carbohydrate restricted diet. Increased biological markers of fatigue such as increased cortisol levels have also been evidenced in athletes on low carbohydrate diets during endurance training (Ihalainen et al., 2014).

It is possible that the increased metabolic stress of low-carbohydrate diets may lead to greater feelings of fatigue and higher rates of perceived exertion during high-intensity exercise. Increased stress from low-carbohydrate diet practices also have the potential to disrupt homeostasis resulting in a hormonal imbalance that could lead to increased feelings associated with depression. In contrast, high carbohydrate diets may attenuate the feelings of fatigue by adequately replacing muscle glycogen after high-intensity workouts and lowering the perceived exertion of the following exercise bout. Therefore, it is hypothesized that athletes with higher dietary carbohydrate intakes will experience less feelings associated with fatigue and depression, and there would be a negative relationship between carbohydrate intake (CHO) and negative mood scores in trained distance runners.
CHAPTER IV

METHODS

Subjects were recruited from The University of Akron Track Team. There were 24 athletes (N=24) who agreed to participate in the research study with only 12 participants (N=12) included in results due to non-compliance with study requirements. In order to be considered for inclusion, subjects indicated that they planned to compete during the 2016 indoor track season in events ranging from the 800 to 5,000-meters. Participants were excluded if they indicated that they had a known metabolic disorder that would affect their dietary intake or metabolism of carbohydrates. A complete list of exclusion criteria is provided in Appendix A.

Testing took place over an eight-week competitive indoor track season. Prior to beginning any testing, subjects signed an Informed Consent document in which they were informed of the requirements, potential risks, and benefits of involvement in the research study. A copy of the Informed Consent is provided is Appendix A. The Institutional Review Board at the Office of Research Services and Sponsored Programs at The University of Akron approved this study.

Subjects reported to the Exercise Physiology laboratory at The University of Akron week one of the study for initial testing procedures. They were given a mood
questionnaire that included several brief open-ended questions encompassing sleeping habits, illness, and musculoskeletal injury incidence within the past six weeks. The questionnaire also included a Likert-Scale assessment of mood states in which they were asked to rank feelings of fatigue, sadness, anger, worthlessness, and happiness on a scale of 0-4. The total mood scores were calculated by adding scores of negative moods (fatigue, anger, worthlessness, and sadness) and then subtracting scores of the positive mood, happiness. A copy of the questionnaire is provided in Appendix B. All questionnaire items were developed based on current recommendations by the American College of Sports Medicine and European College of Sport Science for identifying overtraining syndrome in athletes (Meeusen et al., 2013). The items on the mood scale were developed based on the Training Distress Scale (TDS), which is an adaptation of the Profile of Mood States (POMS) and has demonstrated validity in assessing mood disturbances in endurance athletes (Raglin & Morgan, 1994). Currently, there is no single assessment procedure that has been validated for the use of diagnosing the presence of overtraining syndrome in athletes.

After completing the mood questionnaire, participants were weighed using a digital medical scale (Doran Scales, Batavia, IL, USA). Body composition was estimated using a GE Prodigy bone densitometer (GE Lunar Corp, Madison, WI, USA). Densitometry procedures took approximately 10 minutes for each subject. Participants were instructed to remove all jewelry and metals, and to lay quietly with arms at their sides on the scanning bed as the scan took place. Total body fat
percentages were recorded from lean and fat mass measurements during densitometry.

Following densitometry procedures, participants completed a VO2max test to determine their aerobic capacity (VO2max). The maximal aerobic test procedure lasted approximately ten to fifteen minutes for the majority of participants. The protocol selected was the Costill-Fox protocol for highly trained subjects. Participants warmed-up for a stage of four minutes at 7.5 mph and then began the testing protocol that consisted of incremental stages at a consistent speed of 8.9 mph at 0% grade and increasing by 2% in grade every two-minutes. The subjects were verbally encouraged to give a maximal effort and the test was terminated once volitional fatigue was achieved. Subjects wore a Korr face mask (Korr VO2 mask, Korr Medical Technologies, Inc., Salt Lake City, Utah) to continuously analyze pulmonary gas exchange variables throughout the test using a metabolic cart (ParvoMedics TruOne 2400, WebWorx Technology, Sandy, Utah) as well as a heart rate monitor (Polar FT1 Heart Rate Monitor, Polar Electro Inc., Lake Success, New York). The initial VO2max test acted as an initial accommodation protocol to familiarize participants with wearing the face mask during maximal exercise and with the test protocol on the treadmill, as none of the participants had previously completed a maximal aerobic test prior to the experimental procedures. Familiarization procedures were performed to ensure accuracy of the VO2max test results during the second trial.

Throughout the course of the eight-week study period participants were asked to keep a 24-hour dietary recall. The dietary recall was recorded on the site
Google docs and was set-up as an individual template for each participant with instructions for logging their daily food intake. The Google docs template was selected as a method to record dietary recall because it did not include recommended total kilocalorie or macronutrient intakes to participants. A sample template is provided in Appendix C. Participants were instructed to record the quantity, brand, and method of preparation for each food item. A registered dietitian analyzed the dietary information of participants using Nutri Calc Plus 3.0 Software (McGraw Hill, Columbus, OH, USA). Analysis of average daily carbohydrate intake in g · kg⁻¹ body weight·day⁻¹ was calculated using an average of three days that represented complete and accurate documentation of food recall and participant weight. An entry was deemed complete and accurate if it contained information on the brand of food item and the quantity consumed in appropriate units of measurement. There were 13 participants excluded from the study because they either failed to record any dietary recall entries or they excluded information such as quantity of food in measurable units that would affect the accuracy of the results.

Laboratory testing procedures took place again one week after the conclusion of the indoor track season during week eight of the study. The participants completed the Mood and Lifestyles Questionnaire, and had their body weight, body fat percentage, and VO₂max reassessed using the same procedures as outlined during their initial visit. Each participant’s VO₂max (ml·kg·min) and time (seconds) until their respiratory exchange ratio (RER) equaled 1.0 (RER 1.0) were obtained from the post-season VO₂max test results.
Statistical Analysis

Statistical analysis was performed using SPSS V 19.0 software. Correlation statistics using Pearson’s product correlation were conducted to analyze the relationships between variables of dietary carbohydrate intake (CHO), aerobic fitness (VO$_{2\text{max}}$), time spent using fat as the primary substrate (RER 1.0), and mood scores. A simple linear regression analysis was then completed between variables demonstrating a strong relationship to predict VO$_{2\text{max}}$, RER 1.0, and mood scores based on CHO. Statistical significance was set a priori at $p < 0.05$. 
CHAPTER V

RESULTS

The purpose of this research study was to determine the relationship between dietary carbohydrate intake (CHO) and endurance performance indicators of aerobic fitness (VO_{2max}), time spent using fat as the primary substrate (RER 1.0), and mood. The relationship between CHO and VO_{2max} and the relationship between CHO and RER 1.0 were analyzed to observe the effects of CHO on endurance adaptations. Additionally, the relationship between CHO and mood scores was analyzed to determine the effect CHO has on the psychological aspects of training and performance.

Table 1

*Participant Physical Characteristics*

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (Years)</th>
<th>Height (cm)</th>
<th>Weight (Kg)</th>
<th>%BF</th>
<th>VO_{2max} (ml ⋅ kg^{-1} ⋅ min^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>20.5 ± 1.41</td>
<td>178.75 ± 7.5</td>
<td>68.91 ± 7.03</td>
<td>8.49 ± 2.97</td>
<td>69.08 ± 4.31</td>
</tr>
<tr>
<td>N= 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>19.25 ± 1.5</td>
<td>167 ± 2.45</td>
<td>54.14 ± 3.62</td>
<td>18.28 ± 5.65</td>
<td>53.05 ± 5.86</td>
</tr>
<tr>
<td>N= 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20.08 ± 1.51</td>
<td>174.83 ± 8.42</td>
<td>63.98 ± 9.38</td>
<td>11.75 ± 6.13</td>
<td>63.73 ± 9.13</td>
</tr>
<tr>
<td>N= 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Values are presented as M ± SD, %BF, body fat percentage
Table 2

Energy and Macronutrient 3-Day Average Intake and Distributions by Sex

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N= 8</td>
<td>N= 4</td>
</tr>
<tr>
<td>EI (Kcal)</td>
<td>2279.37 ± 503.84</td>
<td>1996.22 ± 272.06</td>
</tr>
<tr>
<td>EI DRI met (%)</td>
<td>0 (N=0)</td>
<td>0 (N=0)</td>
</tr>
<tr>
<td>CHO (g ⋅ kg⁻¹ body weight⋅day⁻¹)</td>
<td>3.64 ± .77</td>
<td>5.03 ± .91</td>
</tr>
<tr>
<td>CHO DRI met (%)</td>
<td>0 (N=0)</td>
<td>25.0 (N=1)</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>36.0 ± 9.0</td>
<td>29.0 ± 4.0</td>
</tr>
<tr>
<td>DRI met (%)</td>
<td>100.0 (N=8)</td>
<td>100.0 (N=4)</td>
</tr>
<tr>
<td>PRO (g ⋅ kg⁻¹ body weight⋅day⁻¹)</td>
<td>1.57 ± .33</td>
<td>1.67 ± .38</td>
</tr>
<tr>
<td>PRO DRI met (%)</td>
<td>87.5 (N=7)</td>
<td>75.0 (N=3)</td>
</tr>
</tbody>
</table>

Note: Values are represented as M ± SD
El, energy intake; DRI, daily recommended intake; CHO, carbohydrates; PRO, protein
DRI values taken from AND Joint Position Statement (2016)

Table 2 depicts the average energy and macronutrient three-day intake for participants by sex. There were no males (N= 8) or females (N= 4) that met energy intake recommendations for highly active individuals, with males consuming an average of 2279.37 ± 503.84 Kcals and females consuming 1996.22 ± 272.06 Kcals per day. Both males and females also had average daily intakes less than the DRI of 6-10 g ⋅ kg⁻¹ body weight⋅day⁻¹ for carbohydrate (CHO) intake with males consuming an average of 3.64 ± .77 g ⋅ kg⁻¹ body weight⋅day⁻¹ and females consuming 5.03 ± .91 g ⋅ kg⁻¹ body weight⋅day⁻¹. Both 100% of males (N=8) and females (N=4) consumed met the DRI of greater than 20% total Kcals from fat with males consuming an average of 36.0 ± 9.0% and females 29.0 ± 4.0%. There were 87.5% (N=7) of males
and 75% (N=3) of females that consumed more protein than the DRI of 1.2-2.0 g·kg\(^{-1}\) body weight·day\(^{-1}\) with males consuming 1.57 ± .33 g·kg\(^{-1}\) body weight·day\(^{-1}\) and females consuming 1.67 ± .38 g·kg\(^{-1}\) body weight·day\(^{-1}\).

Table 3

*Descriptive Statistics for CHO, VO\(_{2\text{max}}\), RER 1.0, and Mood Scores*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO (g·kg(^{-1}) body weight·day(^{-1}))</td>
<td>12</td>
<td>2.59</td>
<td>6.36</td>
<td>4.11</td>
<td>1.03</td>
</tr>
<tr>
<td>VO(_{2\text{max}}) (ml·kg(^{-1})·min(^{-1}))</td>
<td>12</td>
<td>46.1</td>
<td>76.3</td>
<td>63.74</td>
<td>9.58</td>
</tr>
<tr>
<td>RER 1.0 (sec)</td>
<td>12</td>
<td>330</td>
<td>885</td>
<td>712.67</td>
<td>167.89</td>
</tr>
<tr>
<td>Mood Score</td>
<td>12</td>
<td>-5</td>
<td>4</td>
<td>-.04</td>
<td>3.32</td>
</tr>
</tbody>
</table>

Note: CHO, carbohydrates; VO\(_{2\text{max}}\), maximal aerobic capacity; RER 1.0, respiratory exchange ratio of 1.0

Table 3 depicts the descriptive statistics for the variables of CHO, VO\(_{2\text{max}}\), RER 1.0, and mood scores. The amount of CHO in g·kg\(^{-1}\) body weight·day\(^{-1}\) for each participant (N=12) ranged from 2.59 to 6.36 g·kg\(^{-1}\) body weight·day\(^{-1}\) (M= 4.11, SD= 1.03). The VO\(_{2\text{max}}\) in ml·kg\(^{-1}\)·min\(^{-1}\) for each participant (N=12) ranged from 46.1 to 76.3 ml·kg\(^{-1}\)·min\(^{-1}\) (M= 63.74, SD= 9.58). The time until RER reached 1.0 in seconds for each participant (N=12) ranged from 330 to 885 seconds (M= 712.67, SD= 167.89). The negative mood score for each participant (N=12) ranged from -5 to 4 for negative moods (M=-.04, SD= 3.32). Assumptions for normality were tested with the Shapiro-Wilk test, and indicated the data were statistically normal (p > .05).
Table 4

*Pearson’s r Correlation for CHO, VO$_{2\text{max}}$, RER 1.0, and Mood Scores*

<table>
<thead>
<tr>
<th></th>
<th>CHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO$_{2\text{max}}$</td>
<td></td>
</tr>
<tr>
<td>Sig (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>RER 1.0</td>
<td></td>
</tr>
<tr>
<td>Sig (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Mood Score</td>
<td></td>
</tr>
<tr>
<td>Sig (2-tailed)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>

* * $p < 0.05$, ** $p < 0.01$

Note: CHO, carbohydrates; VO$_{2\text{max}}$, maximal aerobic capacity; RER 1.0, respiratory exchange ratio of 1.0

Table 4 illustrates correlation statistics for the variables of CHO, VO$_{2\text{max}}$, RER 1.0 and mood scores. A Pearson’s product correlation was conducted to assess the relationships between CHO vs. VO$_{2\text{max}}$, CHO vs. RER 1.0, and CHO vs. Mood Score.

There was a moderate negative relationship between CHO and VO$_{2\text{max}}$, $r(10) = -0.63$, $p < 0.05$, with daily CHO in g·kg$^{-1}$·body weight·day$^{-1}$ explaining 39% of the variation in VO$_{2\text{max}}$ scores when measured in ml·kg$^{-1}$·min$^{-1}$. There was a strong negative relationship between CHO and RER 1.0, $r(10) = -0.79$, $p < 0.01$, with daily CHO in g·kg$^{-1}$·body weight·day$^{-1}$ explaining 63% of the variation in time until RER 1.0 is reached when measured in seconds. There was a moderate positive relationship between CHO and Mood Score, $r(10) = 0.56$, $p < 0.05$, with daily CHO in g·kg$^{-1}$·body weight·day$^{-1}$ explaining 32% of the variation in negative mood scores.
Table 5

*Linear Regression Analysis for CHO and VO_{2max}, CHO and RER 1.0, CHO and Mood Score*

<table>
<thead>
<tr>
<th>Variable</th>
<th>VO_{2max}</th>
<th></th>
<th>RER 1.0</th>
<th></th>
<th>Mood Score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
<td>(\beta)</td>
<td>B</td>
<td>SE B</td>
<td>(\beta)</td>
</tr>
<tr>
<td>CHO</td>
<td>-5.52</td>
<td>2.18</td>
<td>-0.63*</td>
<td>-128.51</td>
<td>31.37</td>
<td>-0.79**</td>
</tr>
<tr>
<td>R^2</td>
<td>.39</td>
<td></td>
<td></td>
<td>.63</td>
<td></td>
<td>.32</td>
</tr>
<tr>
<td>F</td>
<td>6.41*</td>
<td></td>
<td></td>
<td>16.79**</td>
<td></td>
<td>4.63</td>
</tr>
</tbody>
</table>

* p < .05. ** p < .01

Note: CHO, carbohydrates; VO_{2max}, maximal aerobic capacity; RER 1.0, respiratory exchange ratio of 1.0

Table 5 demonstrates linear regression analysis statistics for the CHO and VO_{2max}, CHO and RER 1.0, and CHO and mood scores. A simple linear regression was calculated to predict VO_{2max} based on CHO. A significant regression equation was found (F(1,10) = 6.41, p < .05). VO_{2max} is equal to 86.40 – 5.52 (CHO) g·kg^{-1} ·body weight·day^{-1} when VO_{2max} is measured in ml · kg^{-1} · min^{-1}. VO_{2max} decreases 5.52 ml · kg^{-1} · min^{-1} for each g·kg^{-1} ·body weight·day^{-1}. A simple linear regression was also calculated to predict RER 1.0 based on CHO. A significant regression equation was found (F(1,10) = 16.79, p < .01). RER 1.0 is equal to 1240.41 – 128.51 (CHO) g·kg^{-1} ·body weight·day^{-1} when RER 1.0 is measured in seconds. RER 1.0 decreases 128.51 seconds for each g·kg^{-1} ·body weight·day^{-1}. Simple linear regression was found to be non-significant to predict Mood Score based on CHO. Representations of scatter plots with regression lines for VO_{2max} based on CHO and RER 1.0 based on CHO are displayed in Figure 1 and Figure 2.
Figure 1. Scatter plot with regression line for $\text{VO}_{2\text{max}}$ vs. CHO

Figure 1 demonstrates a scatter plot representation along with a simple linear regression fit line for $\text{VO}_{2\text{max}}$ vs. CHO. The linear regression line depicts $\text{VO}_{2\text{max}}$ as equal to $86.40 - 5.52 \text{ (CHO)} \text{g} \cdot \text{kg}^{-1} \cdot \text{body weight} \cdot \text{day}^{-1}$. 
Figure 2. Scatter plot with regression line for RER 1.0 vs. CHO

Figure 2 demonstrates a scatter plot representation along with a simple linear regression fit line for RER 1.0 vs. CHO. The linear regression line depicts time of RER 1.0 in seconds as $1240.41 - 128.51 \text{ (CHO) g·kg}^{-1}·\text{body weight·day}^{-1}$. 
CHAPTER VI
DISCUSSION FINDINGS SUMMARY

Carbohydrates have an important role in distance runner metabolism by contributing to the overall energy contribution during higher intensity running and in replacing muscle glycogen stores after workouts (Baar & McGee, 2008; Cermak & Van Loon, 2013; Jeukendrup, 2014; Rapoport, 2010). Faster overall performance times and a greater capacity to perform repeated bouts of high intensity work have been evidenced in endurance athletes that consume diets with higher carbohydrate contents (Alghannam et al., 2015; Couto et al., 2015; Foskett et al., 2008; Skein et al., 2012). Higher carbohydrate diets are also suggestive to prevent against symptoms of overreaching syndrome by attenuating against fatigue and negative feelings that have been associated with training disruptions (Burke, 2010; Halson & Jeukendrup, 2004). However, there is recent evidence that suggests diets higher in carbohydrate content may inhibit specific adaptations to endurance exercise. In particular, high carbohydrate diets may prevent against the expression of the PCG-alpha gene that is responsible for the mitochondrial and capillary development that are important indicators in the development of aerobic capacity and fat metabolism capabilities (Baar, 2014; Baar & McGee, 2008; Burke & Kiens, 2006). Therefore, the purpose of the present study was to determine if there is a relationship between
dietary carbohydrate intake and the endurance performance indicators of aerobic capacity, fat metabolism, and overall mood in endurance trained athletes.

The participants in the present study consumed an average dietary carbohydrate intake of 4.11 g·kg\(^{-1}\)·body weight·day\(^{-1}\) (SD=1.03), which is in agreement with other studies that have observed dietary patterns of distance runners in Western cultures. Baranauskas et al. (2015) found European athletes to consume an average of 4.7 (SD=1.5) g·kg\(^{-1}\)·body weight·day\(^{-1}\). Drenowatz et al. (2012) also found a sample of American masters endurance athletes to consume an average of 4.6 g·kg\(^{-1}\)·body weight·day\(^{-1}\) (SD=2.6) during high-volume training and 4.4 g·kg\(^{-1}\)·body weight·day\(^{-1}\) (SD=2.3) during low-volume training periods. Furthermore, Wardenaar et al. (2015) found male ultramarathon runners to consume an average of 4.4 g·kg\(^{-1}\)·body weight·day\(^{-1}\) (SD=1.3) and female ultramarathon runners to consume 4.5 g·kg\(^{-1}\)·body weight·day\(^{-1}\) (SD=1.3). In our present study, males had a relatively lower dietary intake (M=3.64, SD=.77) and females had a relatively higher intake of carbohydrates than observed in previous studies (M=5.03, SD=.91).

There is moderate evidence to support the hypothesis that diets lower in carbohydrates will result in improved aerobic capacity. Results demonstrated a moderate negative relationship (r= -.63) between dietary carbohydrate intake in g·kg\(^{-1}\)·body weight·day\(^{-1}\) and VO\(_{2\text{max}}\). While the regression analysis (F(1,10)=6.41, p < .05) suggests that a lower dietary intake of carbohydrates will predict a higher VO\(_{2\text{max}}\), carbohydrate intake explained only 39% of the variance in VO\(_{2\text{max}}\) scores.
The small coefficient of determination indicates the possibility of other factors existing that are responsible for the difference in aerobic capacity among the trained distance runners.

Previous research supports other factors contributing to VO$_{2\text{max}}$ than carbohydrate intake alone. Burke et al. (2011) found no change in VO$_{2\text{max}}$ among competitively trained cyclists following a three-week period of caloric restriction on a low-carbohydrate diet consisting of 2.51-3.70 g·kg$^{-1}$·body weight·day$^{-1}$, evidencing no relationship between aerobic capacity improvements and carbohydrate intake. Further supporting the variability in VO$_{2\text{max}}$ scores and the existence of other factors that contribute to aerobic capacity development are findings from other research studies that found conflicting endurance performance results in athletes on carbohydrate modified diets. Piacenti et al. (2012) found there was no change in 30-minute time trial performance in master level endurance athletes after a four-week low carbohydrate diet. In contrast, Couto et al. (2015) found that higher carbohydrate diets elicited faster overall 10-kilometer times in trained male adolescent distance runners. Achten et al. (2003) also found 16-kilometer times to improve in trained runners on a high carbohydrate diet. Based on the results from the present study that suggest only a moderate positive relationship between carbohydrate intake and the supporting body of research evidence, it is unclear whether the amount of dietary intake of carbohydrates affects VO$_{2\text{max}}$. 
One possible factor that could account for the variance in VO$_{2\text{max}}$ scores is gender differences. Male participants in the current study had a lower average dietary carbohydrate intake ($M=3.64$, $SD=0.77$) compared with females ($M=5.03$, $SD=0.91$). The male participants also had higher aerobic fitness ($M=69.08$, $SD=4.31$) compared with females ($M=53.05$, $SD=5.86$). It is well supported that males generally have higher VO$_{2\text{max}}$ scores than females of similar training status (American College of Sports Medicine, 2014). The moderate correlation found between carbohydrate intake and VO$_{2\text{max}}$ could have been a reflection of gender differences in aerobic fitness rather than carbohydrate consumption. Yet, research suggests that despite small differences during the menstrual cycle, females display no difference in metabolic substrate use during exercise and are able to store glycogen with equal efficiency as males (Burke et al., 2011; Hausswirth & Le Meur, 2011). Therefore, it is plausible to hypothesize that absolute VO$_{2\text{max}}$ for females could still be improved with lower dietary carbohydrate consumption although they may not reach those of their male counterparts.

Further explaining the lack of answerability of dietary carbohydrates in predicting VO$_{2\text{max}}$ in the present study is the small variation in dietary intake among the participants ($SD=1.03$). The small sample size ($N=12$) that was taken from only one university track team resulted in a homogenous group of participants that displayed little variation in dietary intake habits. Overall, participants consumed low-carbohydrate diets with only one individual meeting the recommendations for endurance athletes consuming an average of $6.36 \text{ g \ CHO} \cdot \text{kg}^{-1} \cdot \text{body weight} \cdot \text{day}^{-1}$.
It is possible that a different relationship could have been observed between carbohydrate intake and VO$_{2\text{max}}$ with a larger sample size that included athletes with higher carbohydrate diets that matched results from previous research studies. Furthermore, endurance athletes in research studies that displayed significant relationships between high carbohydrate intakes and improved aerobic performance consumed greater than seven g·kg$^{-1}$·body weight·day$^{-1}$, which no participants in our study achieved (Achten et al., 2003; Couto et al., 2015).

There is strong evidence to support the hypothesis that diets lower in carbohydrates result in improved fat metabolism capabilities. The results demonstrated a strong negative relationship (r = -0.79) between dietary carbohydrate intake in g·kg$^{-1}$·body weight·day$^{-1}$ and time until RER equaled 1.0 in seconds. Longer time spent under a respiratory exchange ratio of 1.0 suggests that athletes that consumed a lower dietary carbohydrate intake were able to undergo fat oxidation at higher relative intensities for a longer duration. Greater time spent in fat metabolism during high-intensity exercise is a desired metabolic adaptation to endurance training and allows an athlete to perform at a relatively high intensity as a percentage of their VO$_{2\text{max}}$ for a longer time by preventing fatigue.

There is sufficient evidence from previous research to support the findings of the present study. In a population of endurance trained cyclists and triathletes, Cox et al. (2009) found athletes that consumed a low-carbohydrate diet for 28-days exhibited great fat oxidation during steady state and high-intensity cycling, which is
in agreement with the present results. Respiratory exchange ratios were significantly lower during high intensity exercise above lactic threshold for physically active males that consumed a low-carbohydrate diet than a moderate-carbohydrate diet, indicating a greater ability to utilize fat as fuel (Lima-Silva et al., 2009). Similarly, Van Proeyen et al. (2011) found respiratory exchange ratios to be lower and intramyocellular lipid breakdown to be higher during endurance exercise in physically active males in a fasted state compared with those with high carbohydrate availability. Walker et al. (2000) further supports these results with findings of higher respiratory exchange ratios in endurance-trained women that consumed high-carbohydrate diets compared to moderate-carbohydrate diets during high-intensity cycling exercise. These results from previous research studies support the findings of the present study that lower carbohydrate diets elicit greater adaptations in fat metabolism, resulting in greater time spent with respiratory exchange ratios below 1.0.

There is strong evidence to reject the hypothesis that high carbohydrate diets result in improved mood scores in endurance athletes. Results of mood scores as related to carbohydrate intake in the current study suggested that there was a moderate positive relationship ($r = .56$) between carbohydrate intake and negative mood scores. However, a non-significant regression analysis was found between carbohydrates and negative mood scores. It can be concluded from the non-significant linear relationship that the amount of dietary carbohydrate has no effect on predicting negative feelings such as fatigue, anger, sadness, or worthlessness that could disrupt training.
The present findings are in disagreement with other studies that have found significantly increased mood scores and biomarkers of fatigue in endurance athletes on low-carbohydrate diets and improvements in mood in athletes consuming higher dietary intakes. Piacenti et al. (2012) found masters endurance athletes to have increased feelings of depression, fatigue, anger, tension, and decreased vigor after only two-weeks of a low-carbohydrate diet. Similarly, Rosenkranz et al. (2007) found a triathlete to have higher feelings of lethargy and fatigue while on a carbohydrate restricted diet that resulted in a large disruption in training. Biomarkers of fatigue that include increased cortisol and inflammatory indicators have also been evidenced as higher in endurance athletes on low-carbohydrate diets. Ihalainen et al. (2014) observed increased cortisol levels and a greater stress response to exercise training in athletes during periods of low-carbohydrate availability. Findings from the present study that suggest no relationship between dietary carbohydrate intake and negative moods are not in agreement with other previous research studies that suggest low-carbohydrate diets enhance negative feelings of fatigue and cause disruptions in training status.

One possible explanation for the lack of relationship between carbohydrate intake and mood scores in the current study is the theory of responders versus non-responders to carbohydrate-modified diets. There was a large amount of variance (SD=3.32) in mood scores among participants suggesting a high degree of individual variability within the study. Furthermore, the athletes self-selected their food intake and their average daily carbohydrate intake was reflective of normal long-term dietary patterns rather than an experimental manipulation. In contrast, the studies
that demonstrated a negative effect on mood and training habits manipulated the usual dietary intake of the participants, so that those who may have been accustomed to higher carbohydrate diets were placed on low-carbohydrate diets and vice versa (Achten et al., 2004; Piacentini et al., 2012; Rosenkranz et al., 2007).

Supporting the present results are findings from a case study of three individual marathoners conducted by Stellingwerff (2012). Results from the study demonstrated a high degree of individual variability between the marathoners with those who had previous experience adopting low-carbohydrate fueling strategies experiencing less disruptions and feelings of lethargy than those who had no previous experience (Stellingwerff, 2012). Previous findings along with those found in the present study support the notion of individual variability in response to low-carbohydrate training strategies and explain the non-significant relationship between negative mood scores and carbohydrate intake.

Further explaining the lack of relationship between mood scores and carbohydrate intake are the differences in other macronutrient intakes of fat and protein among athletes in the present study. Although no athlete (N=0) met dietary recommendations for total energy intake (Kcals), the majority exceeded recommended fat (N=12) and protein (N=10) intake. Specifically, the additional protein intake may have prevented athletes, despite a low energy and carbohydrate intake, from becoming overtrained by aiding in recovery. The Academy of Nutrition and Dietetics (2015) confirms that ingesting protein during post-exercise recovery period leads to greater increases muscle protein synthesis and nitrogen balance, thereby enhancing the recovery process. Burke et al. (2012) further advocates for
the addition of protein beyond the recommended amounts for athletes in periods of training in low energy balance and low-carbohydrate availability to maintain lean muscle mass and preserve performance. In the study conducted by Ferguson et al. (2009), trained cyclists were able to maintain their power and two-hour cycling intensity during a period caloric restriction with low carbohydrate availability by maintaining fat and protein intake. The fact that nearly all (N=10) athletes in the present study met or exceeded dietary recommendations for fat and protein could explain the non-significant relationship with mood scores and the relationship with performance indicators of aerobic capacity and fat metabolism. Future research is needed to evaluate similar relationship between carbohydrate intake and performance indicators in a population of athletes that fall below the recommended dietary macronutrient intakes for fat and protein and are at greater risk for anorexia and the female athlete triad.

There are further limitations in the 24-hour recall dietary analysis process used that could have contributed to the variation in mood score results. The use of supplement and ergogenic aid information including caffeine, multivitamins, calcium, Vitamin D, and iron was not included in the analysis. The National Collegiate Athletic Association allows athletes to consume up to 500 milligrams of caffeine two to three hours prior to competition (2014). According to Baar (2014) this allowance meets recommendations for the 200 mg necessary to decrease ratings of perceived exertion during training sessions with low carbohydrate availability. Since the supplement information was not required in the dietary recall, athletes in the current study could have experienced improved mood scores and
decreased fatigue during training sessions despite having low energy and carbohydrate availability due to caffeine ingestion. Future research is recommended to evaluate the use of caffeine along with low-carbohydrate dietary practices in endurance athletes.

Furthermore, it is well established that dietary recall procedures typically result in underreporting of actual dietary intake from participants (AND, 2016). In the current study, athletes were being closely monitored by their coaches and could have felt insecure to include sensitive information such as alcohol or substance use in their dietary logs. The inclusion of alcohol could have impacted the total amount of carbohydrates consumed for participants and affected the relationship between carbohydrate intake and performance indicators of aerobic capacity and fat metabolism. Methods to increase compliance to the dietary recall procedures and decreased feelings of insecurity should be implemented in future studies and include shortening the duration of recall length to several days rather than weeks and employing a registered dietitian to explain information such as quantity and preparation methods of food items.

Summary

Competitive endurance athletes will use dietary strategies to gain enhanced endurance adaptations to training by manipulating macronutrient contents such as carbohydrates (Stellingwerff, 2012). However, manipulation of carbohydrate intake outside of the ranges provided by leading organizations on nutritional recommendations such as those outlined by Academy of Nutrition and Dietetics (2016) have been met with unclear performance improvements. Recently, low-
carbohydrate training sessions have been adopted by endurance athletes and include training with low-glycogen availability and incomplete re-fueling strategies after exercise sessions (Baar, 2014; Stellingwerff, 2012). Some research findings have demonstrated augmented endurance adaptations to low-carbohydrate dietary practices in athletes (Baar 2014; Baar & McGee, 2008; Burke & Kiens, 2006). In contrast, others have suggested decreased capacity to perform high-intensity exercise and higher disruptions in training as a result of low-carbohydrate availability (Alghannam et al., 2015; Couto et al., 2015; Foskett et al., 2008; Skein et al., 2012). Therefore, it was the aim of the present research study to investigate the relationship between carbohydrate intake and endurance capabilities in trained athletes. Specifically, the relationships between carbohydrate intake and aerobic capacity, fat metabolism during high-intensity aerobic exercise, and mood was observed.

It was originally hypothesized that lower dietary intakes of carbohydrate would result in improved aerobic capacity (VO_{2max}). Although a moderate negative relationship exists between VO_{2max} and dietary carbohydrate intake, the relationship is not strong enough to exclude extraneous outside factors that could account for differences in aerobic capacity among trained endurance athletes. In the present study, gender differences in dietary habits could have contributed to the negative relationship found. Males had higher VO_{2max} and consumed a lower average intake of carbohydrates compared with females whom had a lower VO_{2max} and higher average intake of carbohydrates. Previous research studies confirm these findings by suggesting no relationship or conflicting evidence between carbohydrate intake and
aerobic endurance performance (Ferguson et al., 2009; Piacentini et al., 2012). Thus, although regression analysis proved significant, there is evidence to reject the hypothesis that low carbohydrate dietary practices result in improved aerobic capacity. Therefore, it is concluded based on insufficient results from the present study and supporting evidence from previous literature that dietary intake of carbohydrates is not a significant predictor of aerobic capacity. Future studies could include analyzing dietary habits and comparing VO$_{2\text{max}}$ of endurance athletes using a larger sampling frame.

It was also hypothesized that lower dietary intake of carbohydrates would result in improved fat metabolism capabilities and hence a greater time spent below a respiratory exchange ratio of 1.0 (RER 1.0). There is sufficient evidence to accept this hypothesis and to suggest that lower carbohydrate intake results in a greater time spent below RER 1.0 based on a strong negative correlation (r=-.79) between variables and a significant regression analysis (p < .01). Furthermore, sufficient findings from previous research studies support this hypothesis by providing evidence of lower respiratory exchange ratios and improved fat metabolism capabilities with lower carbohydrate intakes (Cox et al., 2010; Lima-Silva et al., 2009; Van Proeyen et al., 2011; Walker et al., 2000). Therefore, there is sufficient evidence to accept the hypothesis that lower carbohydrate intakes will result in a greater time spent below a respiratory exchange ratio of 1.0 (RER 1.0). Regression analysis is significant (p < .01) and can be used to predict the amount of time spent below RER 1.0 in trained endurance runners during VO$_{2\text{max}}$ protocol. Future studies
could include further analysis of fat metabolism by observing muscle biopsies to
determine the actual rate of lipid breakdown.

Lastly, it was hypothesized that higher dietary intake of carbohydrates would
result in improved overall mood scores and decreased feelings of anger,
worthlessness, sadness and fatigue. There was not sufficient evidence to support the
hypothesis based on only a moderate correlation and non-significant linear
regression analysis between variables. The present findings are not in agreement
with previous literature, which widely supports that high carbohydrate dietary
practices attenuate negative feelings that may disrupt training practices (Ihalainen
et al., 2014; Piacentini et al., 2012; Rosenkranz et al., 2007; Stellingwerff, 2012). The
discrepancies in findings between the present study and previous research findings
are explained by the differences in experimental procedures. The present study was
observational and participants self-selected their carbohydrate intake. Whereas,
studies that found statistically significant positive relationships experimentally
modified carbohydrate intake to achieve low- and high-carbohydrate groups of
participants (Achten et al., 2004; Piacentini et al., 2012; Rosenkranz et al., 2007).
Some participants could have responded to the carbohydrate modification, while
others may not have responded or had an adverse response.

There were limitations in the 24-hour recall method used to collect dietary
information on the athletes. The use of supplements, most notably caffeine, was not
included in dietary recall. Caffeine could have mitigated the increased perceived
exertion and central nervous system fatigue of low-carbohydrate training sessions.
Furthermore, the eight-weeks time period in which participants were asked to log
nutritional data decreased compliance. Future studies should include shortened dietary recall time periods of several days and information regarding supplements.

Limitations

The major limitations in the present research study existed in the dietary log practices. There were twelve participants that were excluded for issues of non-compliance with dietary logging procedures. Over the eight-week dietary recall period, there were only three days of information for each of the remaining twelve participants that were considered accurate by the registered dietitian and could be used in the data. The issues that prevented other logs to be used included inappropriate measurement quantities used to log food such as bowls, one serving, or plates and failure to identify specific details of food items. For example, with regards to supplements, a participant may have written that they consumed an amino acid supplement, but neglected to include brand information.

Further limitations of the study existed in the scale used to assess mood state in the Mood and Lifestyle Questionnaire. While this scale was adopted from the Profile of Mood States (POMS) and Training Distress Scale (TDS), which are validated assessments of mood states in athletes, the assessment is vulnerable to both intra- and inter-subject variability. The feelings included in the Likert-scale of fatigue, anger, sadness, and worthlessness could be interpreted differently between subjects and within the subject on different days of assessment. The reliability of these methods on accurately assessing mood states is questionable because of its sensitive subjectivity.
Practical Applications

Results of the present study that observed the dietary habits of performing collegiate distance runners and the effect their self-selected carbohydrate intake has on aspects of endurance performance could be applied to other populations of highly-trained endurance athletes. While lower dietary carbohydrate intakes were moderately associated with improved measures of aerobic capacity (VO$_{2\text{max}}$) and strongly associated with fat oxidation capabilities (RER 1.0), low-carbohydrate diets should be implemented with careful consideration among athletes. The timing of these dietary strategies in periods of low-intensity, long duration work such as in the preparatory phase before the competitive season could be useful in further maximizing the aerobic adaptations to training among endurance athletes, specifically by improving fat metabolism capabilities. Athletes should also consider supplementing low-carbohydrate availability sessions with caffeine and additional protein ingestion to mitigate the increased rates of perceived exertion and fatigue (AND, 2016; Baar, 2014; Burke et al., 2012). During more intense periods of training such as in the specific preparatory and competition phase, proper re-fueling strategies should be emphasized to prevent against accumulative fatigue from high-intensity workouts and competitions. Furthermore, coaches should acknowledge the concept of non-responders and responders to low-carbohydrate diets and should monitor athletes closely to observe for changes in mood and performance.

Future Directions

Future research studies should take into account the limitations associated with the dietary logging procedures in the present study and consider alternative
ways to assess dietary recalls of participants. The length of the recall period should be limited to maintain compliance. In the present study, only three days of useful information could be collected. Therefore, it is recommended that further studies should consider a dietary recall period of three to five days in length. Furthermore, with the dietary recall procedures, measures should be taken to help ensure participants are providing accurate representations of all food they are consuming. It may be useful to consider apps that allow the participant to take photos of their meals to prevent underestimation or neglect in including certain food items. It should also be recommended for a dietitian to be actively involved in the dietary recall process in the initial phase of implementation to instruct participants on how to measure food using appropriate quantities and which details to include in the log. A dietitian could also possibly be involved during the actual recall process to meet with participants and ensure all the information is included within their logs at the end of each 24-hour recall period.

Future research studies should also consider finding an alternative assessment to evaluate mood state in athletes that is practical and relies less on interpretation of subjective feelings. The present Likert-scale assessment used in the Mood and Lifestyle Questionnaire listed only the intensity of feelings experienced over the previous week. In order to reduce the amount of subjectivity within this assessment, the question could be rephrased to ask how the intensity of each feeling varies from their usual state. For example, an assessment could ask the participant, “How fatigued do you feel compared to normal?” Responses could include “somewhat more than normal,” “normal,” “a great deal more than normal,”
“less than normal,” etc. Assessing participant’s moods around how they individually feel on an everyday basis could reduce the amount of subjectivity associated with asking only the intensity of those feelings.

There are multiple directions for further research studies based on the current data collected from the present study. One example of a future research study could be to include fat, kilocalories, along with carbohydrates in a multiple linear regression analysis to predict indicators of endurance performance such as aerobic capacity, fat metabolism efficiency, and mood states. Including multiple factors would allow for a more complex analysis and suggest which dietary variable is the strongest predictor of endurance performance. Additionally, to contribute to the practicality of study results as applied to coaches and athletes, further linear analysis could be performed to determine if a correlation exists between carbohydrate intake and body weight or composition. Finally, additional correlation analysis could be conducted to examine the relationship between carbohydrate intake and actual performance times in endurance events to determine if endurance adaptations are being translated into improved performance.
REFERENCES


APPENDIX A

INFORMED CONSENT FORM
PROTOCOL TITLE: Relationship between carbohydrate intake, bone mineral density, and performance in collegiate track runners

Informed Consent Form
For Prospective Collection of Data/Information

INTRODUCTION: You are invited to participate in a research study conducted by Marissa Baranauskas, Jordan T. Olson, and Dr. Ronald Otterstetter in the School of Sport Science and Wellness Education at The University of Akron. The purpose of the study is to evaluate certain parameters that could potentially affect maintenance of performance over the course of an indoor track season. Physiological, psychological, overall performance, and nutritional habits will be assessed throughout the course of a competitive season. Maximal aerobic capacity (VO$_{2\text{max}}$), resting metabolic rate, and bone density will all be assessed via laboratory procedures. You will be required to record your dietary and training habits daily in a journal. Additionally, participants will be responsible for completing a brief mood and lifestyle questionnaire several times throughout the study. From the information collected, we hope to gain a better understanding of potential factors that could contribute to performance decreases in collegiate athletes.

PROCEDURES: Testing will take place the weeks of January 10$^{th}$ to January 16$^{th}$ and February 29$^{th}$ to March 6$^{th}$ 2016 at The University of Akron Physiology Laboratory, which is located in Rm. 407 of Infocision Stadium. You will sign up for testing dates and times. You will sign up for a 15-minute session to assess your bone density and a 30-minute session to test your maximal aerobic capacity. Subjects will be expected to refrain from consuming food and to be normally hydrated two-hours prior to all testing procedures. You will also be expected to wear comfortable, loose, athletic clothing and running shoes for all laboratory proceduresBone density and body composition with be assessed via Dual Energy X-Ray Absorptiometry (DEXA). For this procedure, you will be asked to remove all jewelry and metals and to lay quietly with your arms at your sides on a scanning table for the duration of the test. The bone scan will began at your head and progress slowly to your feet. The bone
density scan will provide us with information about your total average bone density, regional bone density, lean mass, and fat mass.

Maximal aerobic capacity will be assessed using VO$_{2\text{max}}$ test protocol for highly trained subjects on a treadmill. Testing will take approximately 12-15 minutes. This test requires you to exercise at a near maximal intensity. Test procedures follow running at a consistent speed of 8.9 mph at 0% grade and then increasing grade by 2% every two-minutes. You will be wearing a heart rate monitor and facial mask that encloses your entire mouth and nose and may make breathing difficult. The test will be terminated once you reach certain physiological parameters indicative of a maximal effort as determined by the test administrator. You are also free to terminate the test at any time by indicating you would like to stop.

Outside of the laboratory procedures, you will be asked to record all training and dietary practices from January 10th to March 6th. You will record your diet and physical activity at the conclusion of each day during the study period. You will be given access to a Google Doc template to electronically record your daily food intake and you will be asked to record daily training on the Running2Win site.

**EXCLUSION:** Only subjects who are current members of The University of Akron Track team and plan to compete in the 2016 indoor track season will be eligible for participation in the research study. If you have a known metabolic disorder such as thyroid disease, are taking thyroid medications, are pregnant, have had multiple x-rays or a CT scan within the last year, or have a diagnosed bone injury you are ineligible to participate. Please check the attached list to see if you can be included in the research study.

**RISKS:** There are minor risks and/or discomforts associated with bone density and VO$_{2\text{max}}$ procedures. All research participants will be exposed to minimal amounts of radiation that are emitted during DEXA scan procedures. If you have undergone an x-ray or CT-scan in the past year your risk of suffering adverse effects from radiation exposure are elevated. If you have undergone an x-ray or CT-scan in the past year your risk of suffering adverse effects from radiation exposure are elevated. The United States Nuclear Regulatory Commission (USNRC) cites 1 mSv of radiation exposure as the allowed dose from man-made sources such as medical procedures that is associated with a low level of risk. A single x-ray gives doses of radiation as high as .70 mSv and full-body CT scans give 10 mSv. DEXA scans gives 0.001 mSv per single dose, so for testing purposes you will be exposed to a total of 0.002 mSv of radiation. The health hazards of an annual radiation exposure greater than 1 mSv are increased risk of cancer, irreversible cell and DNA damage.

The risks associated with VO$_{2\text{max}}$ testing are similar to those of high-intensity physical activity. The incidence of risk for healthy, well-trained subjects is near zero.
BENEFITS: The benefits of participating in this research study are that you will learn information that valuable to your training such as bone density, body composition, and aerobic fitness.

RIGHT TO REFUSE OR WITHDRAW: Participation in this research study is voluntary and you have the right to refuse to participate or withdraw from the study at any time.

ANONYMOUS AND CONFIDENTIAL DATA COLLECTION: The data collection process will be confidential. Any identifying information collected will be kept in a secured location that only the researchers have access to. Participants will not be identified by name and the only information linking your identity to study results will be a key that links numbers to identifying information. The list identifying your name with a corresponding code number will be kept on a department issued laptop that is secured by a locked password and locked in the advisor’s office. All other documents that identify you with a code number ie. DEXA and VO₂max results will be stored in a locked filing cabinet in the advisor’s office. Your identity and test results will not be shared with anyone who is not affiliated with the research study.

WHO TO CONTACT WITH QUESTIONS: If you have any questions about this study, you may contact Marissa Baranauskas (440) 223-7837, Jordan Olson (513) 314-0631 or the research advisor Dr. Ronald Otterstetter at (330) 972-7738. This project has been reviewed and approved by The University of Akron Institutional Review Board. If you have any questions about your rights as a research participant, you may call the IRB at (330) 972-7666.

ACCEPTANCE & SIGNATURE:

I have read the information provided above an all of my questions have been answered. I fully understand the risks and benefits associated with participation in this research study and the expectations of my participation have been clearly explained. I voluntarily agree to participate in this study. I will receive a copy of this consent form for my information.

________________________________________   __________________________
Participant signature                      Date
EXCLUSION CRITERIA

• Pregnancy
• Multiple x-rays or a CT scan within the past year
• Current Bone Injury
  ▪ Diagnosed with a stress reaction, stress fracture or complete bone fracture within the last 6 weeks
• Thyroid Disease
  ▪ Hypothyroidism
  ▪ Hyperthyroidism
  ▪ Hashimoto's Disease
  ▪ Graves' Disease
• Taking thyroid medication
  ▪ Synthroid
  ▪ Levothyroxine
  ▪ Armour Thyroid
  ▪ Levoxyl
  ▪ Cytomel
• Taking a medication that influences bone metabolism
  ▪ Antacids containing aluminum
  ▪ Antiseizure medications Dilantin or Phenobarbital
  ▪ Cancer chemotherapeutic medications
  ▪ Cyclosporine
  ▪ Gonadotropin releasing hormone Lupron and Zoladex
  ▪ Heparin
  ▪ Lithium
  ▪ Depo-Provera
  ▪ Methotrexate
  ▪ Proton Pump Inhibitors Nexium, Prevacid, Prilosec
  ▪ Selective Serotonin Reuptake Inhibitors (SSRIs) Lexapro, Prozac, Zoloft
  ▪ Steroids (glucocorticoids) Cortisone and Prednisone
  ▪ Thiazolidinediones Actos and Avandia
APPENDIX B

MOOD AND LIFESTYLE QUESTIONNAIRE
Mood and Lifestyle Questionnaire

How do you feel today? (Circle your response)

Based on current and past training do you identify yourself as either a middle distance (800m-1500m) or long distance (3,000m-5,000m) runner?

How many hours on average did you sleep per night over the previous week?

How many hours on average do you normally sleep per night?

Have you developed any of the following sicknesses in the past month?

- Respiratory infection-
  - common cold, sore throat, fever
- Influenza
- Pneumonia
- Streptococcus
- Mononucleosis
- Bronchitis
- Hepatitis
- Meningitis
- Chickenpox
- Herpesviruses

Do you have a current diagnosis of an eating disorder?

Have you had a musculoskeletal overuse injury within the past month?

- Stress reaction
- Stress fracture
- Complete fracture
- Medial tibial stress syndrome (shin splints)
- Tendonitis
  - Achilles
  - Patellar (knee)
  - Hamstring
  - Quadriceps
- Ligament sprain/strain
- ACL
- MCL
- PCL
- Posterior tibial (ankle)
- Muscle strain
  - Hamstring
  - Quadriceps
  - Calf

Have you ever been diagnosed with any existing inflammatory diseases and any other chronic illnesses?

- HIV
- Diabetes
- Systemic inflammatory disease
- Rheumatoid arthritis
- Myocarditis
- Heart valve issues
- Abnormal heart arrhythmias
Have you felt extremely fatigued or exhausted for > 4 weeks? ______

On the chart below, indicate (by circling) the choice that best represents the intensity of each mood you have felt over the previous week.

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little bit</th>
<th>Somewhat</th>
<th>Quite a bit</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Anger</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Happiness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Fatigue</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Worthless</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
APPENDIX C

DIETARY LOG TEMPLATE
Dietary Journal Guidelines

You will be asked to complete a training and dietary journal for the entirety of this research study, which takes place from January 10th - March 6th, 2016. At the conclusion of each day you should write the given information in a separate journal entry. Listed below are guidelines to follow while writing your journal entries. Please include all information.

1. Date/ Time
2. Dietary
   a. Include all meals, snacks, condiments and beverages in detail (ie. % fat milk, reduced-fat cheese, regular or diet soda)
   b. Include name brands (ie. “PowerBar Harvest Energy- Chocolate Peanut Butter Protein Bar” rather than “chocolate protein bar”)
      i. If the item was obtained at a restaurant or fast food place, include the name of the location (ie. Chipotle Burrito with...)
   c. Describe how it was prepared (ie. grilled, baked, fried, steamed, raw)
   d. Include any supplements
   e. Include the serving size in measurable units
      i. Tsp, tbl, cup, ½ cup, ¼ cup, 1/8 cup, oz, g, # of servings

<table>
<thead>
<tr>
<th>DATE/TIME</th>
<th>FOOD ITEM</th>
<th>BRAND/HOW IT'S PREPARED</th>
<th>AMOUNT</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/20/15</td>
<td>2% Milk with vitamin D</td>
<td>Horizon</td>
<td>1 cup</td>
<td>H</td>
</tr>
<tr>
<td>8:00am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/20/15</td>
<td>Whole Eggs</td>
<td>England’s Best/ Scrambled</td>
<td>2</td>
<td>H</td>
</tr>
<tr>
<td>8:00am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D

HUMAN SUBJECTS APPROVAL FORM
Notice of Approval

Date: January 6, 2016
To: Marissa Barauskas; Jordan Olson,
Sport Science and Wellness Education
From: Sharon McWhorée, IRB Administrator
IRB Number: 20151206
Title: Relationship Between Carbohydrate Intake, Bone Mineral Density, and Performance in Collegiate Track Runners

Thank you for submitting your Application for Research Involving Human Subjects to the IRB for review. Your protocol represents minimal risk to subjects and has been approved.

Approval Category: Expedited
Approval Date: January 5, 2016
Expiration Date: January 5, 2017
Continuation Application Due: December 5, 2016

In addition, the following is/are approved:
- Research involving children
- Research involving prisoners
- Waiver of documentation of consent
- Waiver or alteration of consent

- IRB approval is given for not more than 12 months. If your project will be active for longer than one year, it is your responsibility to submit an Application for Continuation prior to the expiration date.
- If changes are made to the protocol before the expiration date you must submit a Request for Change form for review and approval before the change is implemented.
- When the project is completed you must submit a Final Report to close the IRB file.
- If this research is being conducted for a master’s thesis or doctoral dissertation, you must file a copy of this letter with the thesis or dissertation.
- All forms are available on the ORA website at http://www.uakron.edu/research/ora/irb/irbforms.dot
- CITI Certification is valid for three years. Any continuation of this protocol or approval of new research is contingent upon maintaining a current CITI certification. It is your responsibility to update your certification as needed. The link to the CITI home log-in screen is: https://www.citiprogram.org/

☑ Approved consent form(s) attached

Ohio’s Polytechnic University
Uniting the Arts & Humanities with Science & Technology
The University of Akron is an Equal Education and Employment Institution – Affirmative Action